EGU21-14338, updated on 29 Jun 2022
https://doi.org/10.5194/egusphere-egu21-14338
EGU General Assembly 2021

Modeling the Physiological Responses of a Desert Shrub to Rainfall Pulses in an Arid Environment

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A physically-based model for soil-plant-atmosphere continuum (SPAC) is parameterized and evaluated against field-measured physiological responses of a desert shrub, Haloxylon Ammodendron (HA), to rainfall pulses in a desert environment in northwestern China. Despite its simplicity, the model was successfully employed to assess the complexity and uncertainty involved in the physiological responses of HA following pulsed rainfall events. Through modelling efforts, we report a systematic evaluation of the non-linear relationship between the physiological responses of HA and pulse magnitude or antecedent moisture. The results show that following the rainfall pulses, the modeled daily transpiration and assimilation rates either stayed the same or decreased monotonically with water stress. However, the stomatal conductance (g_s) and photosynthetic rate (A_n) responses were relatively weaker when compared to the increase in water potential. We found that rainfall events with <5 mm cannot induce any substantial response of A_n (Δ<4μmol $m^{-2}s^{-1}$), and at least 13 mm of rain is required to increase A_n by 10 μmol $m^{-2}s^{-1}$. Significant responses of water use efficiency (WUE) were not even discernible from viewing the simulation. Our analysis reproduced the judgements with a certain uncertainty that HA is basically a kind of drought resistant species, it tends to have a more conservative water-use strategy and thus a safer photosynthetic behavior. The inverse–texture hypothesis is much more clearly supported by the modeling experiments, suggesting that soil texture drives differences in the effects of pulses on the magnitude and sensitivity of the physiological responses of plants, and the interaction between rainfall and soil texture may lead to the preferred acquisition and use of pulsed precipitation by HA. The modelling work and findings in this study is likely to shed light on the quantitative understanding of the physiological behavior of other plants in water-limited environments.